Princeton University

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EVIDENCE FOR VAPOR
BUBBLE LUMINESCENCE

G.T. Reynolds

Technical Report #1

January 14, 2000

ONR Grant N00014-00-1-0010

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Evidence for Vapor Bubble Luminescence

The observation of light at deep sea hydrothermal vents at wavelengths in the visible from 450 nm to 650 nm [1] can not be explained as thermal radiation at the observed temperatures ($\sim 350°$).

The physical processes that have been considered as possible explanations include sonoluminescence. Sonoluminescence (SL) is a phenomenon in which light is emitted when a liquid is cavitated in some manner. [2, 3] In laboratory studies the cavitation is usually excited by ultrasonic sources of 20 KHz to MHz, and the light results from the implosion of bubbles of radius less than 100 μm. Leighton and Walton have shown the presence of bubbles in various conditions of running water, breaking waves, etc. [4]. There is good reason to believe that bubbles can occur in vent fluid (Figure 1) and these might be excited to oscillate and implode. SL has been shown to occur when a liquid flows through a Venturi tube, a water jet impacts on a stationary plate or a spark discharge occurs in a liquid. SL has not been observed when liquids boil, electrolysis, or by the action of a propeller. [5]

However, early in 1999 A.J. Walton, working in the Cavendish Laboratory, Cambridge, reported seeing light from a process associated with macroscopic vapor bubbles, [6] when superheated steam bubbles condensed in water.

The steam was produced in a domestic cappuccino machine, adapting the usual frothing attachment to a glass tube which ended several centimeters below the water surface in a rectangular tank. The tip was viewed with a home-made microscope coupled to a 4 stage high gain image intensifier. On introducing a steady stream of bubbles into the tank a bright emission was evident on the output phosphor of the intensifier, and recorded photographically in 20 second exposures. Due to the nature of the source of the bubbles, Walton initially called this "cappuccino luminescence", but prior to publication dignified it as "Vapor Bubble Luminescence" (VBL).

Walton's results are conclusive, but it was decided to repeat the experiment for confirmation using a photomultiplier detector in our Princeton Laboratory. The photomultiplier has the advantage of providing time resolution within the 20 sec interval of bubble formation.

The photomultiplier used to register the signal was an RCA 8575 run at 1700 volts. The photomultiplier was housed in a light tight cylinder, with a

top insert that accommodated at 100 ml beaker into which the output tube of the cappuccino frothing tube fixture was inserted, and through which the superheated steam was ejected into the water in the beaker, which was at room temperature. The final orifice, through which the steam entered the water was variously 1 mm and 3 mm in diameter. The steam bubbles were introduced by opening the valve of the frothing device just after the boiling began and water started to flow into the cup in the usual fashion.

Examples of the recorded photomultiplier output are shown in Figs. 2 and 3. Figure 2 shows the result when steam was introduced to sea water and Fig. 3 the result when steam was introduced into tap water. The recording chart ran at 40 mm per minute, so that the signal is $\sim$ 18 sec duration, consistent with Walton's 20 sec exposures. The difference in the response between tap and sea water is interesting but must be considered preliminary, awaiting a more extended investigation of the various parameters involved.

Following the photomultiplier experiment an attempt was made to record the luminescence using an intensified CCD camera (Hamamatsu C2400-32) with a Century Optics 17 mm f.95 lens, focused approximately 3 cm from the bubble formation. No convincing signal was observed from tap water. A very weak signal was detected from sea water, but it was obvious that integration of frames for 10 sec or so would be necessary for a more convincing demonstration.

A full characterization of the luminescence requires spectral information. Walton has reported observing a weak spectrum, just above noise level, indicating a broad continuum slightly enhanced toward the blue.

In view of the relevance of VBL to light observed at deep sea hydrothermal vents, it is worthwhile to consider an experiment using ALISS (Ambient Light Imaging and Spectral System) to look for the luminescence in sea water. This instrumentation has the capability of providing time resolution or integration and spectral information. The luminescence observed in such a laboratory experiment would not be complicated with thermal radiation, as is in the vent observations.

References

[1] C.L. Van Dover, G.T. Reynolds, A.D. Chave, and J.A. Tyson, Geophys. Res. Lett. **23**, 2049-2052 (1996).

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[3] P.B. Barber, R.A. Miller, R. Lofstedt, R. Putterman, and K.R. Weninger, Phys. Rep. **281**, 65-143 (1997).

[4] T.G. Leighton and A.J. Walton, Eur. J. Phys. **8**, 98-104 (1987).

[5] R. Latorre, Acustica **42**, 132-141 (1981).

[6] A.J. Walton, private communication.

Figures

Fig. 1 Boiling and Bubble Formation in vents, from D.A. Butterfield *et al.*, JGR, **95**, 895-921 (1990).

Fig. 2 Photomultiplier response to steam bubbling in sea water.

Fig. 3 Photomultiplier response to steam bubbling in tap water.

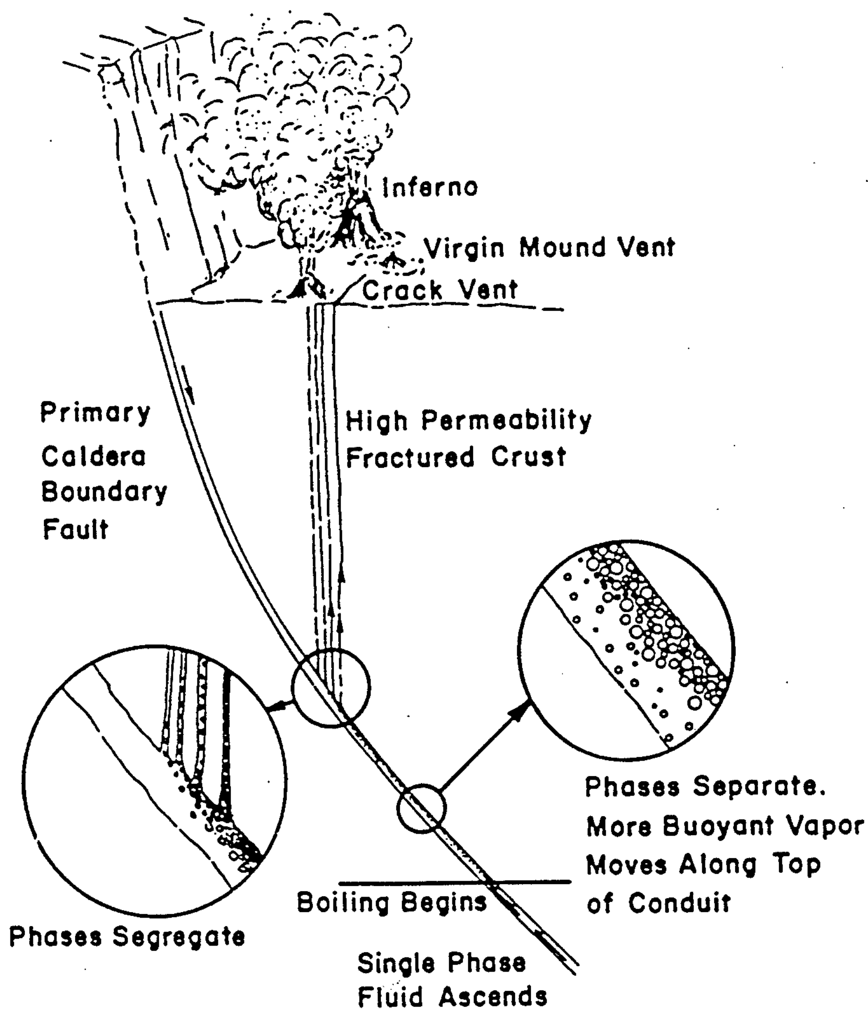
Inferno
Virgin Mound Vent
Crack Vent
Primary
Caldera
Boundary
Fault
High Permeability
Fractured Crust
Phases Separate.
More Buoyant Vapor
Moves Along Top
of Conduit
Boiling Begins
Phases Segregate
Single Phase
Fluid Ascends

FIGURE 1

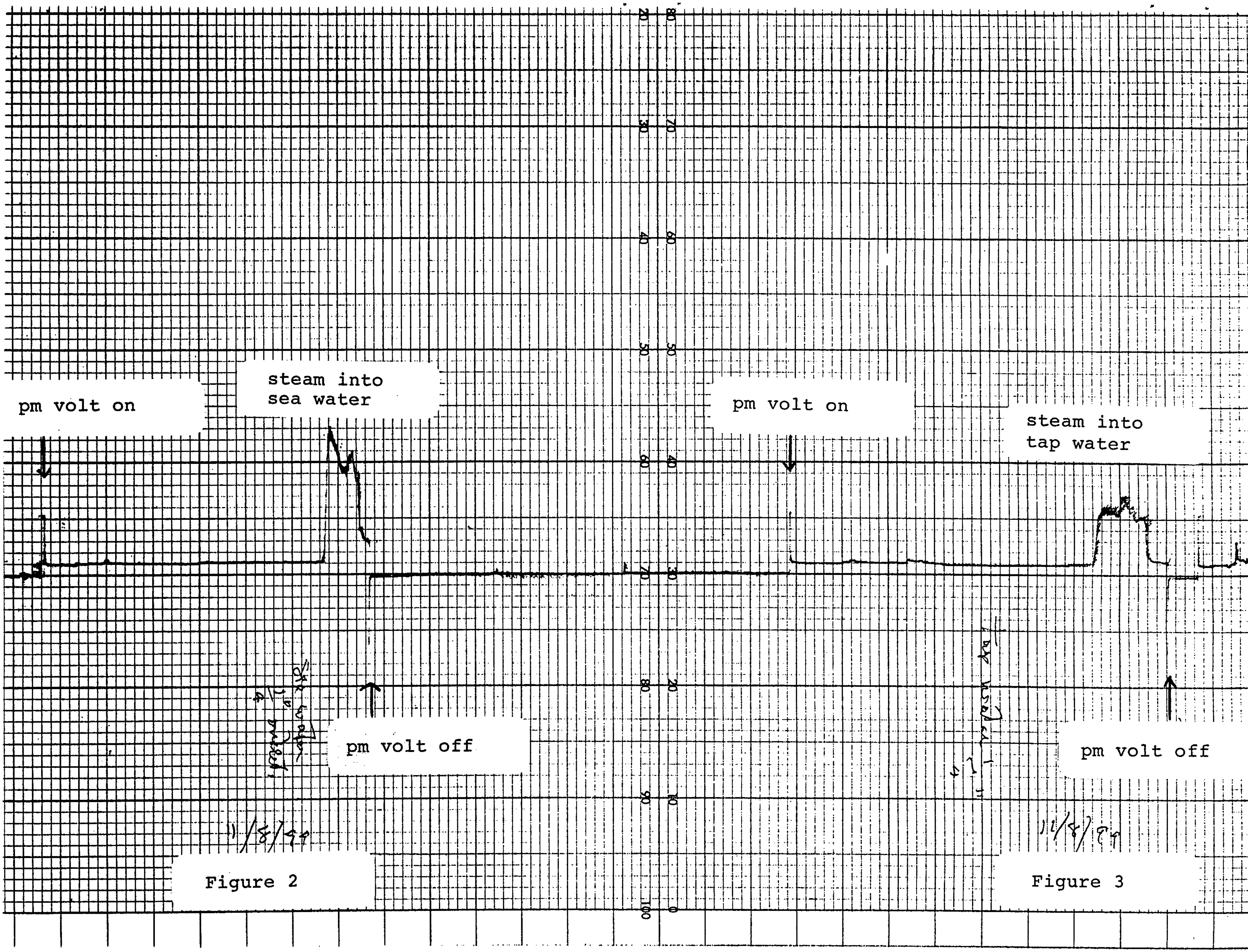

Figure 2

Figure 3

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT DATE	3. DATES COVERED *(From - To)*
18-01-2000	Technical	10/99 -- 01/00

4. TITLE AND SUBTITLE

Evidence for Vapor Bubble Luminescence

5a. CONTRACT NUMBER

PR -- 00PR00102-00

5b. GRANT NUMBER

N00014-00-1-0010

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Reynolds, George T.

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

The Trustees of Princeton University
Office of Research, Project Administration
Fifth Floor New South Building
Princeton,NJ 08544-0636

8. PERFORMING ORGANIZATION REPORT NUMBER

PHYS-1

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Office of Naval Research Regional Office Boston
495 Summer Street Room 627
Boston, MA 02210-2109

10. SPONSOR/MONITOR'S ACRONYM(S)

ONR (73)

11. SPONSORING/MONITORING AGENCY REPORT NUMBER

12. DISTRIBUTION AVAILABILITY STATEMENT

APPROVED FOR PUBLIC RELEASE

13. SUPPLEMENTARY NOTES

14. ABSTRACT

A novel type of luminescence has been studied from steam vapor bubbles condensing in sea water and tap water. A possible application to the light observed at deep sea hydrothermal vents is discussed.

15. SUBJECT TERMS

Vapor bubbles, luminescence, deep sea vent light.

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
U	U	U	UU	6	Geo. T. Reynolds
					19b. TELEPONE NUMBER *(Include area code)* (609) 258-4384

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI-Std Z39-18